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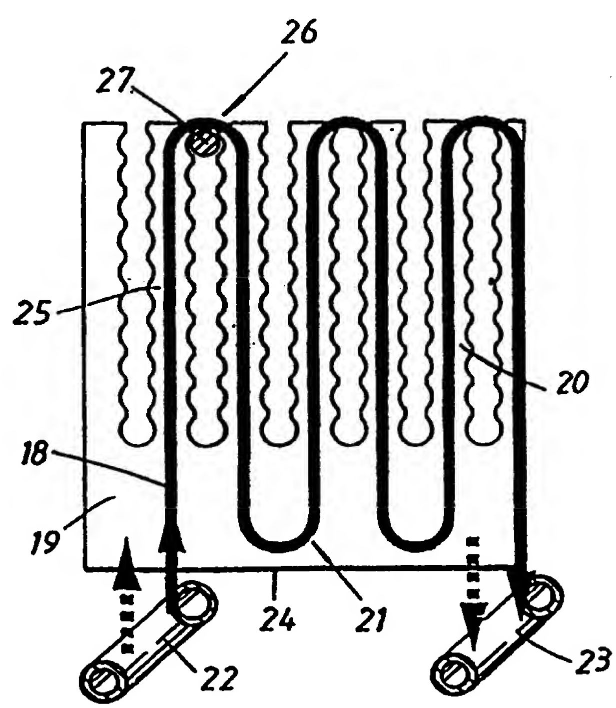
(54) Title: ROTARY ELECTRIC MACHINE WITH RADIAL COOLING

(57) Abstract

A rotating electric machine comprising a stator (1) wound with a high-voltage cable and provided with stator teeth (4) extending radially inwards from an outer yoke portion (5), wherein at least one stator tooth (4) is connected to at least one cooling tube (18) running radially in the stator tooth (4) and connected to a cooling circuit (34) in which coolant (36) is arranged to circulate and wherein the cooling is arranged to take place over at least most of the axial extension of the stator tooth (4), and also a method of cooling a rotating electric machine provided with high-voltage stator windings, wherein th stator is cooled by a coolant (36) being caused to circulate in a cooling circuit (34) through cooling ducts running radially through the stator teeth (4).



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ROTARY ELECTRIC MACHINE WITH RADIAL COOLING

TECHNICAL FIELD:

The present invention relates to rotating electric machines such as synchronous machines, but also double-fed machines, applications in asynchronous static current converter cascades, outer pole machines and synchronous flux machines, as well as alternating current machines intended primarily as generators in a power station for generating electric power. The invention relates particularly to the stator of such machines and to an embodiment for cooling the stator teeth and thus indirectly also to the insulated electric conductors constituting the stator winding.

BACKGROUND ART:

Similar machines have conventionally been designed for voltages in the range 15-30 kV and 30 kV has normally been considered to be an upper limit. In the case of generators, this usually means that a generator must be connected to the power network via a transformer which steps up the voltage to the level of the power network - in the range of approximately 130-400 kV. The present invention is intended for use with high voltages, by which implies in the first place voltages exceeding 10 kV. A typical working range for a device according to the invention may be 36-800 kV.

By using high-voltage insulated electric conductors, in the following termed cables, in the stator winding, with solid insulation similar to that used in cables for transmitting electric power, e.g., crosslinked polyethylene (XLPE) cables), the voltage of the machine can be increased to such levels that it can be connected directly to the power network without an intermediate transformer. The conventional transformer can thus be eliminated. The concept generally requires that the slots in which the cables are placed in the

stator be deeper than regards conventional technology (thicker insulation due to higher voltage and more turns in the winding). The loss distribution will therefore differ to that of a conventional machine, which in turn entails new problems with regard to cooling the stator teeth, for instance.

Two different air-cooled systems exist in conventional cooling: radial cooling where the air passes the rotor through the hub and radial ducts in the rotor, and axial cooling where the air is blown into the air gap with the aid of axial fans.

The stator is then divided into radial air ducts formed by (usually straight) spacers which are welded in place. Due to the poor thermal conductivity axially through the stator laminations, the air ducts must be frequently repeated. The drawback with air cooling is that the ventilation losses are considerable and that the stator must be longer due to the ventilation ducts. The ventilation ducts may also result in a weak mechanical structure, especially in said high-voltage generators with long teeth.

Water-cooled systems, e.g., instead of air-cooled systems for high-voltage generators have the advantage that the radial ventilation ducts can be eliminated, resulting in shorter machines while at the same time increasing the efficiency. Water-cooled systems for stators in large alternating current machines are often based on hollow winding parts i.e. the electric conductors are hollow with longitudinal ducts for the coolant, in certain cases combined with cooling tubes inserted axially in the stator yoke. Constructions are known in which the stator yoke is cooled using aluminium blocks inserted at regular intervals along the axial extension of the stator. However, there is no example of direct cooling of the stator teeth with such

cooling clamps since these are cooled indirectly through the water-cooling of the stator winding.

It is considered that coils for rotating generators can be manufactured with good results within a voltage range of 3 - 25 kV.

Attempts to develop generators for higher voltages, however, have been in progress for a long time. This is obvious, e.g., from "Electrical World", October 15, 1932, pages 524-525. This paper describes how a generator designed by Parson 1929 was arranged for 33 kV. It also describes a generator in Langerbrugge, Belgium, which produced a voltage of 36 kV. Although the article also speculates on the possibility of increasing voltage levels still further, the development was curtailed by the concepts upon which these generators were based. This was primarily because of the shortcomings of the insulation system where varnish-impregnated layers of mica oil and paper were used in several separate layers.

With reference to a report from the Electric Power Research Institute, EPRI, EL-3391 from April 1984, an account is given of generator concepts for achieving higher voltage in an electric generator with the object of connecting such a generator to a power network without intermediate transformers. Such a solution is assessed in the report as offering good gains in efficiency and considerable financial advantages. The main reason that it was deemed possible in 1984 to start developing generators for direct connection to power networks was that a superconducting rotor had been developed at the time. The considerable excitation capacity of the superconducting field winding allows the use of airgap-winding with sufficient thickness to withstand the electrical stresses.

By combining the concept deemed most promising according to the project, that of designing a magnetic circuit with winding, known as "monolithe cylinder armature", a concept in which two cylinders of conductors are enclosed in three cylinders of insulation and the whole structure is attached to an iron core without teeth, it was assessed that a rotating electric machine for high voltage could be directly connected to a power network. The solution entailed the main insulation having to be made sufficiently thick to withstand network-to-network and network-to-earth potentials. Obvious drawbacks regarding the proposed solution, besides its demanding a superconducting rotor, are that it also requires extremely thick insulation, which increases the machine size. The end windings must be insulated and cooled with oil or freones in order to control the large electric fields at the ends. The whole machine must be hermetically sealed in order to prevent the liquid dielectric medium from absorbing moisture from the atmosphere.

Certain attempts at a new approach as regards the design of synchronous machines are described, inter alia, in an article entitled "Water-and-oil-cooled Turbogenerator TVM-300" in J. Elektrotechnika, No. 1, 1970, pp. 6-8, in US 4,429,244 "Stator of Generator" and in Russian patent document CCCP Patent 955369.

The water- and oil-cooled synchronous machine described in J. Elektrotechnika is intended for voltages up to 20 kV. The article describes a new insulation system consisting of oil/paper insulation, which makes it possible to immerse the stator completely in oil. The oil can then be used as a coolant while at the same time using it as insulation. To prevent oil in the stator from leaking out towards the rotor, a dielectric

oil-separating ring is provided at the internal surface of the core. The stator winding is made from conductors with an oval hollow shape provided with oil and paper insulation. The coil sides with their insulation are secured to the slots made with rectangular cross section by means of wedges. As coolant, oil is used both in the hollow conductors and in holes in the stator walls. Such cooling systems, however, entail a large number of connections of both oil and electricity at the end windings. The thick insulation also entails an increased radius of curvature of the conductors, which in turn results in an increased size of the winding overhang.

The above-mentioned US patent relates to the stator part of a synchronous machine which comprises a magnetic core of laminated sheet with trapezoidal slots for the stator winding. The slots are tapered since the need for insulation of the stator winding is less towards the interior of the rotor where the part of the winding which is located nearest the neutral point is disposed. In addition, the stator part comprises a dielectric oil-separating cylinder nearest the inner surface of the core which may increase the magnetization requirement relative to a machine without this ring. The stator winding is made of oil-immersed cables with the same diameter for each coil layer. The layers are separated from each other by means of spacers in the slots and secured by wedges. What is special regarding the winding is that it comprises two so-called half-windings connected in series. One of the two half-windings is located, centred, inside an insulation sleeve. The conductors of the stator winding are cooled by surrounding oil. The disadvantages with such a large quantity of oil in the system are the risk of leakage and the considerable amount of cleaning work which may result from a fault condition. Those parts of the insulation sleeve which are located outside the

slots have a cylindrical part and a conical termination reinforced with current-carrying layers, the purpose of which is to control the electric field strength in the region where the cable enters the end winding.

From CCCP 955369 it is clear, in another attempt to raise the rated voltage of the synchronous machine, that the oil-cooled stator winding comprises a conventional high-voltage cable with the same dimension for all the layers. The cable is placed in stator slots formed as circular, radially located openings corresponding to the cross-section area of the cable and the necessary space for fixing and for coolant. The different radially located layers of the winding are surrounded by and fixed in insulated tubes. Insulating spacers fix the tubes in the stator slot. Because of the oil cooling, an internal dielectric ring is also needed for sealing the coolant against the internal air gap. The design shown has no tapering of the insulation or of the stator slots. The design exhibits a very narrow radial waist between the different stator slots, which implies a large slot leakage flux which significantly influences the magnetization requirement of the machine.

DE 2917717 shows a cooling segment for cooling medium in an electric machine. The segment comprises internal cooling ducts disposed in the segment.

US 3,447,002 shows a stator core provided with a plurality of annular grooves, in which heat conducting bodies are located, arranged tangentially one after the other in each groove with cooling tubes embedded in the cooling bodies.

US 2,217,430 shows a dynamo electric machine with means for cooling the stator for such a machine by the circulation of water through the stator core.

According to the present invention direct cooling of the teeth is a necessity and the stator winding is therefore cooled indirectly. The teeth are also exceptionally long in comparison with conventional generators and this also necessitates direct cooling of the teeth.

OBJECT OF THE INVENTION:

The object of the present invention is to provide an arrangement of the type described in the introduction which will permit direct cooling of the stator teeth while cooling the cables constituting the stator winding indirectly. Advantageous further developments of the invention are indicated in the following description.

SUMMARY OF THE INVENTION:

The present invention relates to an arrangement for cooling the stator teeth, and indirectly the stator winding, in a high-voltage electric machine such as a high-voltage alternating current generator.

The arrangement comprises radially-running tubes, electrically insulated, and placed in loops through the stator teeth at a certain axial distance from adjacent loops. The arrangement also comprises radially extending cooling clamps containing cooling tubes in which coolant circulates. The cooling clamps are inserted in the stator at approximately the same axial distance as conventional air-ventilation ducts. The tubes run along the entire radial length of the stator teeth.

According to a particularly preferred embodiment of the invention, at least one of the semiconducting layers, preferably both, have the same coefficient of thermal expansion as the solid insulation. The decisive benefit

is thus achieved that defects, cracks or the like are avoided at thermal movement in the winding.

BRIEF DESCRIPTION OF THE DRAWINGS:

The invention will be described in more detail with reference to the accompanying drawings.

Figure 1 shows schematically a perspective view of a section taken diametrically through the stator of a rotating electrical machine.

Figure 2 shows a cross sectional view of a high-voltage cable according to the present invention,

Figure 3 shows schematically a sector of a rotating electric machine,

Figure 4 shows a first embodiment according to the present invention,

Figure 5 shows schematically a second embodiment according to the present invention

Figure 6a-6d show sections through one of each of four embodiments of cooling-tube teeth according to the invention,

Figure 7 shows a cooling circuit according to the present invention.

DESCRIPTION OF THE INVENTION:

Figure 1 shows part of an electric machine in which the rotor has been removed to show more clearly the arrangement of a stator 1. The main parts of the stator 1 constitute a stator frame 2, a stator core 3 comprising stator teeth 4 and an outer yoke portion 5 defining a stator yoke. The stator also comprises a stator winding 6 composed of high-voltage cable situated in a space 7 shaped like a bicycle chain, see Figure 3, formed between each individual stator tooth 4. In Figure 3 the stator winding 6 is only indicated by its electric conductors. As can be seen in Figure 1, the stator winding 6 forms a end-winding package 8 on both sides of the stator 1. It is also clear from

Figure 3 that the insulation of the high-voltage cables has several dimensions, arranged in groups depending on the radial position of the cables in the stator 1.

In larger conventional machines the stator frame 2 often consists of a welded sheet steel construction. In large machines the stator core 3, is generally formed of 0.35 mm sheet of electrical steel divided into stacks with an axial length of approximately 50 mm, separated from each other by 5 mm ventilation ducts forming partitions. In a machine according to the present invention, however, the ventilation ducts are eliminated. In large machines each stack of laminations is formed by fitting punched segments 9 of suitable size together to form a first layer, after which each subsequent layer is placed at right angles to produce a complete plate-shaped part of a stator core 3. The parts and the partitions are held together by pressure legs 10 pressing against pressure rings, fingers or segments, not shown. Only two pressure legs are shown in Figure 1.

Figure 2 shows a cross-sectional view of a high-voltage cable 11 according to the invention. The high-voltage cable 11 comprises a number of strands 12 of copper (Cu), for instance, having circular cross section. These strands 12 are arranged in the middle of the high-voltage cable 11. Around the strands 12 is a first semiconducting layer 13, and around the first semiconducting layer 13 is an insulating layer 14, e.g. crosslinked polyethylene (XLPE) insulation. Around the insulating layer 14 is a second semiconducting layer 15. Thus, the concept "high-voltage cable" in the present application does not include the outer protective sheath that normally surrounds such cables for power distribution.

Figure 3 shows schematically a radial sector of a machine with a segment 9 of the stator 1 and with a rotor pole 16 on the rotor 17 of the machine. As can be seen the stator winding 6 is arranged in the space 7 in the shape of a bicycle chain, formed between each stator tooth 4. Each stator tooth 4 extends radially inwards from the outer yoke portion 5.

Figure 4 shows a simplified view of a first embodiment of the invention with a cooling tube 18 forming a cooling tube loop in a cooling clamp 19 having substantially the same shape as the segment 9, with tooth parts 20 between which the characteristic slot resembling a bicycle chain is formed. Figures 4 and 5 have been simplified to rectangular shape in order to simply illustrate the principles of the embodiments. According to Figure 3 a cooling tube loop 21 is formed by one end of the cooling tube 18 being connected to an inlet loop 22 and its other end being connected to an outlet loop 23.

A coolant thus flows in the cooling tube 18 from the inlet loop 22 at the outer side 24 of the cooling clamp, into the cooling clamp 19, and into a cooling clamp stamp 25 towards its tip, whence the cooling tube 18 passes from tooth to tooth in a space 26 formed between the air gap and an uppermost high-voltage cable 27. This space is taken up by a slot wedge, not shown, which can be visualized cut at the transition of the tube, allowing passage for said tube. This slot wedge can also be divided into about thirty small wedges to allow place for the tube bends. An advantageous embodiment of a cooling clamp in the present invention may be a tube cross section formed by bending the tube to a rectangular shape which is then formed into loops, the cooling tube loops being permanently cast in aluminium on a lid.

Figure 5 shows a simplified view of a second embodiment of the invention with a cooling tube 18 forming a cooling tube loop in a cooling clamp 19 of substantially the same design as the segment 9 with tooth parts 20 between which the characteristic slot resembling a bicycle chain is formed. According to Figure 5 a cooling tube loop 21 is formed in this embodiment by one end of the cooling tube 18 being connected to an inlet loop 22 and its other end being connected to an outlet loop 23.

A coolant thus flows in the cooling tube 18 from the inlet loop 22 at the outer side 24 of the cooling clamp, into the cooling clamp 19, and into a cooling clamp stand 25 towards its tip, whence the cooling tube turns at the tip, see the arrow, and extends back outwardly in the same cooling clamp stand to once again form a similar tooth loop in the next tooth.

In this embodiment also a cooling clamp may be produced with rectangular cross section of the tube by bending. The tube is then formed into loops, the cooling tube loops being permanently cast in aluminium on a lid or attached to an intermediate steel beam with casting compound. XLPE-tubes with intermediate steel beams can also be embedded and formed suitably as cooling clamps consisting of stator profiles separated by steel spaces, partially filled with filler compound, e.g. cured plastic.

The advantage of the embodiment according to Figure 4 is that the tube acquires a larger bending radius than if it was to return to the same tooth as in Figure 5.

As indicated in Figures 4 and 5, adjacent cooling clamps are shown by dotted arrows as connected in parallel to inlet and outlet loops.

Figures 6a-6d illustrate different embodiments according to Figures 4-5, in sections through the cooling clamp stands. Figure 6a shows a section through a cooling clamp stand according to Figure 4 showing an advantageous embodiment in which the cooling tube 18 of steel has been bent to substantially rectangular cross section, and the cooling tube has subsequently been embedded in an aluminium block 28 provided with a cover plate 29. The aluminium block may also be manufactured in two halves which are fitted together around the cooling tube. Figure 6b shows a section through a cooling clamp stand according to Figure 4 the cooling tube 18 of the tooth running between two beams 30, preferably of steel, acting as spacing and reinforcing beams during assembly of the cooling tube. After assembly of the cooling tube with the steel beams, spaces are formed which are then filled with a casting compound 31. Figure 6c shows a section through a cooling clamp stand according to Figure 5. In this embodiment the cooling clamp has been produced by a flexible hollow spacer around a beam 30, preferably of steel, being placed in a loop and the intermediate space filled with a casting compound 31, after which the hollow spacer is removed thus forming a tubular duct 32. Figure 6d also shows a section through a cooling clamp tooth according to Figure 5 in which a flexible cooling tube 33 of XLPE-tube type, is placed in a cooling tube loop around a beam 30, preferably of steel.

The embodiments of cooling media ducts in a cooling clamp stand shown here can be varied in many ways within the scope of the appended claims. A cast aluminium block, for instance, can be made in two pieces with ducts for insertion of cooling tubes of steel or of XLPE-tube type. The cross-section of the cooling tube may vary from circular to oval or be substantially rectangular.

An outer cooling circuit is arranged, see Figure 7, in which all cooling tubes 18 are connected to a closed cooling circuit 34, which in the embodiment shown comprises a tank 35 containing the coolant 36 which may be water, hydrogen gas or other coolant for the circuit. The tank 35 is provided with a level indicator for control and monitoring of the coolant level. The tank 35 is also connected to two distribution circuits consisting of an inlet loop 37 and an outlet loop 38. Between the inlet loop 37 and outlet loop 38 a number of cooling clamps 19, shown schematically in Figure 7, are arranged, each comprising at least one cooling tube loop 21. All cooling clamps 19 are connected in parallel between the inlet loop 37 and the outlet loop 38. The coolant 36 is thus arranged to circulate from the inlet loop 37 simultaneously through every cooling tube loop 21 connected in parallel to the outlet loop 38 and on to a circulation pump 39 and a circulation filter 40 through a heat exchanger 41, e.g. a plate heat exchanger, and then back to the inlet loop 37. Water with a temperature of approximately 15°C is supplied from a water reservoir via the exchanger filter, not shown, of an exchanger pump 42. The water is pumped through the exchanger and back to the water reservoir.

A water cooling system according to the present invention may consist, e.g., of cooling clamps provided with tubes inserted approximately every 5 cm along the entire stator. If the stator segments are glued the spacing between cooling clamps can be greater than 5 cm.

Since the cooling clamp must be able to support the full weight of the stator if mounted vertically, plus the pressure from any pressure rings (a total pressure in the region of 0.5 MPa), a mechanically supporting

structure is incorporated in the cooling clamp as shown in Figures 6a-d. The cooling tubes may be of stainless steel or they may be polymer as mentioned earlier, e.g. XLPE-tubes, Wirsbo-inPEX®, which have been hot-bent directly on the cooling plate with steel spacers as bending template. The steel spacers are welded in the same way as for conventionally air-cooled stators and also take up axial forces in the same way. XLPE-tubes may also be flattened in a furnace at a temperature of approximately 130°C and are then correctly positioned as the cover plates are pressed down on them. The plates are then welded or glued. It is important that the cooling tubes are "flat" and relatively large in order to provide a sufficient cooling surface. Steel tubes can be made smaller than XLPE-tubes. The casting compound can be made sufficiently heat conducting by means of, e.g., quartz-filled epoxy. The air pockets can be filled with casting compound afterwards, as shown earlier.

The invention is not limited to the embodiments as examples. Several modifications are feasible within the scope of the invention. Thus the cooling tubes may be of metal or polymer. The cooling plates may also be cast aluminium blocks. An interesting possibility is also to use the stator laminations as supporting structure and casting compound in the remaining spaces.

CLAIMS

1. A rotating electric machine, comprising a stator (1) wound with a high-voltage cable and provided with stator teeth (4) extending radially inwards from an outer yoke portion (5), characterized in that the machine comprises a winding comprising an insulation system including at least two semiconducting layers, each layer constituting essentially an equipotential surface and also including solid isolation disposed therebetween, and that at least one stator tooth (4) is connected to at least one cooling tube (18) running radially in the stator tooth (4) and connected to a cooling circuit (34) in which coolant (36) is arranged to circulate and that the cooling is arranged to take place over at least most of the axial extension of the stator tooth (4).

2. A machine as claimed in claim 1, characterized in that at least one of the layers has substantially the same coefficient of thermal expansion as the solid insulation.

3. A machine as claimed in any of claims 1-2, characterized in that the cooling tube (18) is arranged to extend from the outer yoke portion (5) in through a cooling clamp stand (25) and at the tip of the cooling clamp stand (25) passes over to the tip of the next cooling clamp stand (25) and then again out through this cooling clamp stand (25) to the outer yoke portion (5), forming a cooling tube loop.

4. A machine as claimed in any of claims 1-3, characterized in that the cooling tube (18) is arranged to extend from the outer yoke portion (5) in through a cooling clamp stand (25) and at the tip of the cooling clamp stand (25) turn and passes back out

through the said cooling clamp stand (25) to the outer yoke portion (5), forming a cooling loop (21).

5. A machine as claimed in either of claim 3 or claim 4, characterized in that cooling tube loops (21) are arranged in at least one cooling clamp (19) of substantially identical shape as a stator cross section.

6. A machine as claimed in claim 5, characterized in that cooling tubes (18) are arranged to be cast in the cooling clamp (19).

7. A machine as claimed in claim 6, characterized in that the axial distance between the cooling clamps (19) is maximum 200 mm.

8. A machine as claimed in any of claims 3-7, characterized in that the cooling tube loop (21) is provided with at least one beam (30) arranged in the loop.

9. A method of cooling a rotating electric machine provided with high-voltage stator windings, characterized in that the stator is cooled by a coolant (36) being caused to circulate in a cooling circuit (34) through cooling ducts running radially through the stator teeth (4).

10. A method as claimed in claim 9, characterized in that the coolant (36) is caused to circulate in a closed circuit which passes through a heat exchanger (41) cooling the circuit (34) with water from a water reservoir.

11. A machine as claimed in any of claims 1-8, characterized in that the potential of said

first layer is substantially equal to the potential of the conductor.

12. A machine according to claim 11, characterized in that said second layer is arranged to constitute substantially an equipotential surface surrounding said conductor.

13. A machine according to claim 12, characterized in that said second layer is connected to a predetermined potential.

14. A machine according to claim 13, characterized in that said predetermined potential is earth potential.

15. A machine according to any one of the claims 11-14, characterized in that at least two adjacent layers have substantially equal thermal expansion coefficients.

16. A machine according to any one of the claims 1-8 or any one of the claims 11-15, characterized in that said current-carrying conductor comprises a number of strands, only a minority of said strands being non-isolated from each other.

17. A machine according to any one of the claims 1-8 or any one of the claims 11-16, characterized in that each of said three layers is fixed connected to adjacent layer along substantially the whole connecting surface.

18. A machine having a magnetic circuit for high voltage comprising a magnetic core and a winding, characterized in that said winding is formed of a cable comprising one or more current-carrying conductors, each conductor having a number of strands, an inner semiconducting layer provided around each conductor, an insulating layer of solid insulating material provided around said inner semiconducting

layer, and an outer semiconducting layer provided around said insulating layer.

19. A machine according to claim 18, characterized in that said cable also comprises a metal shield and a sheath.

Fig. 1

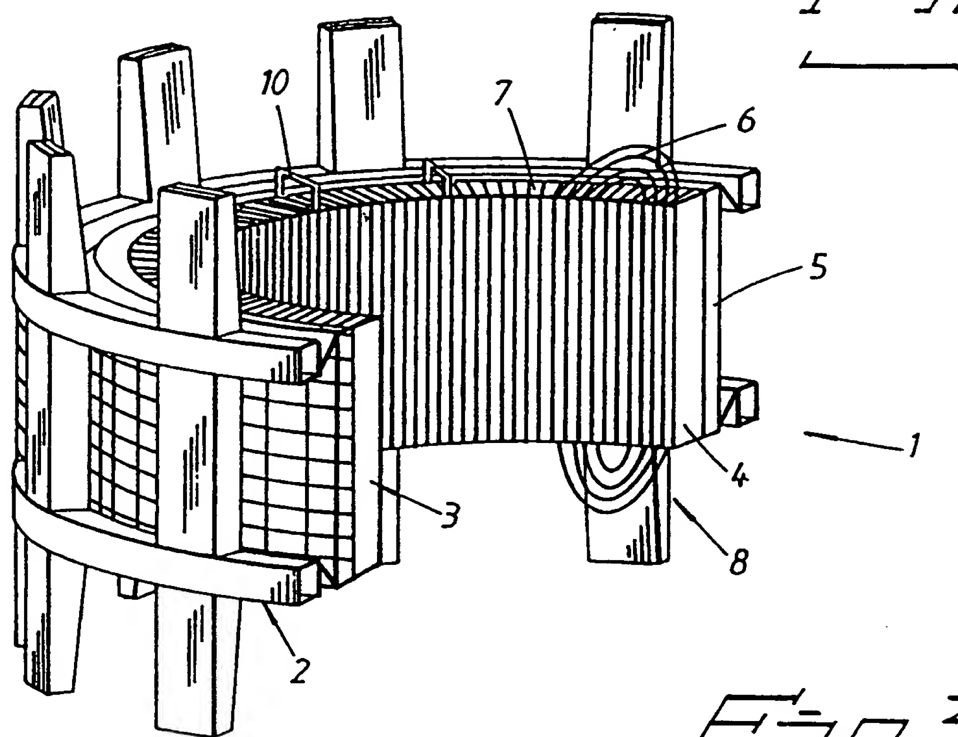

Fig. 3

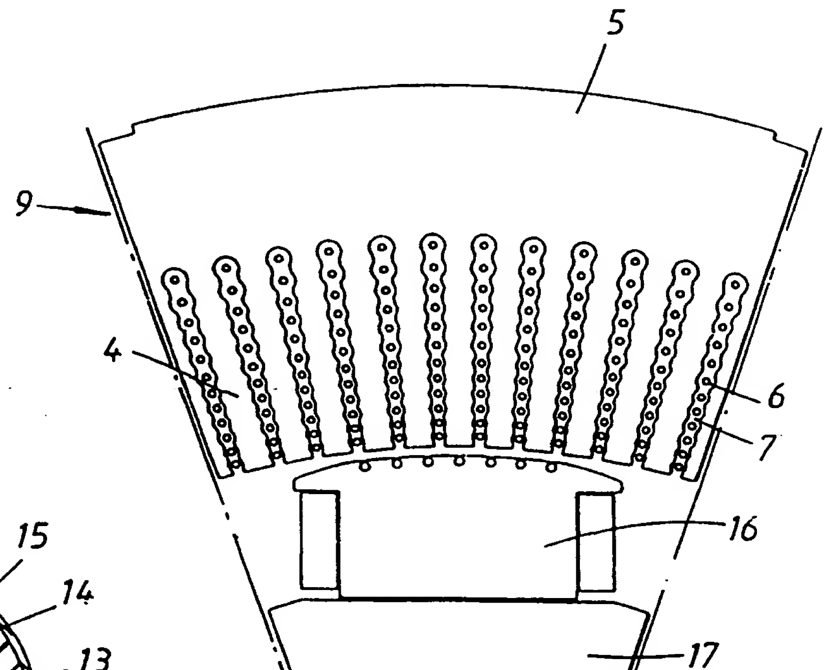

Fig. 2

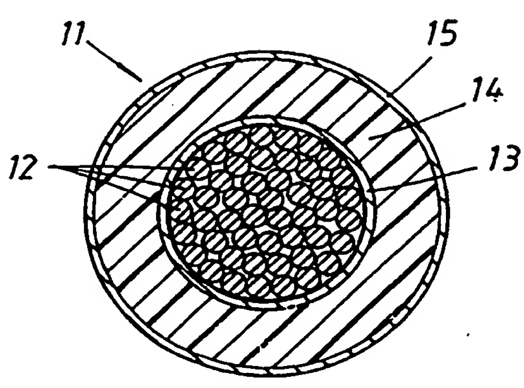

Fig. 4

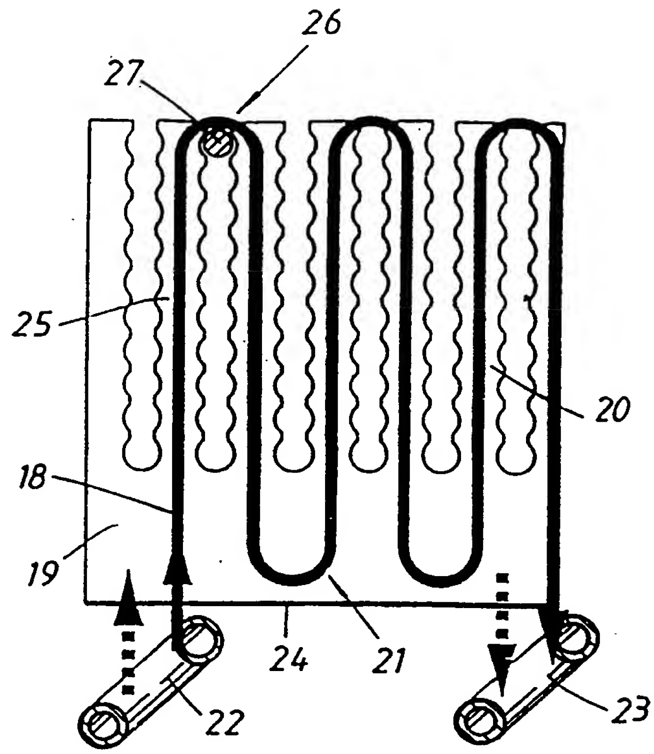

Fig. 5

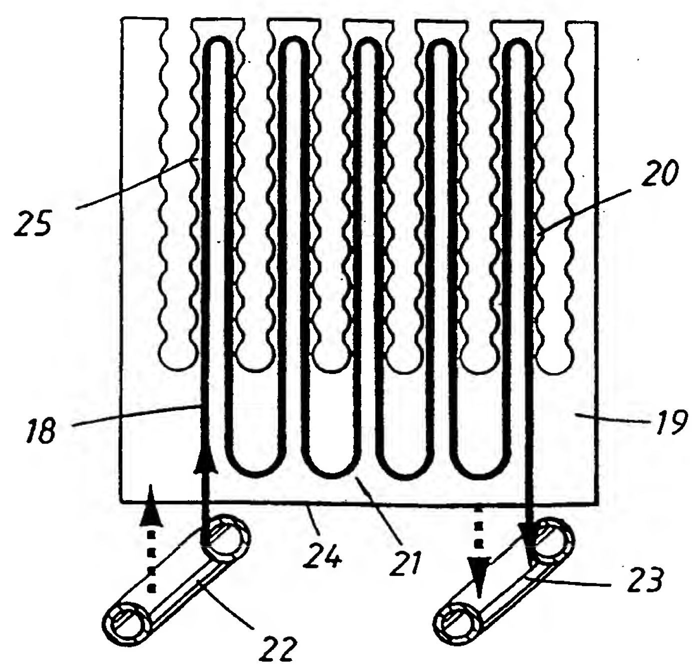

Fig. 6

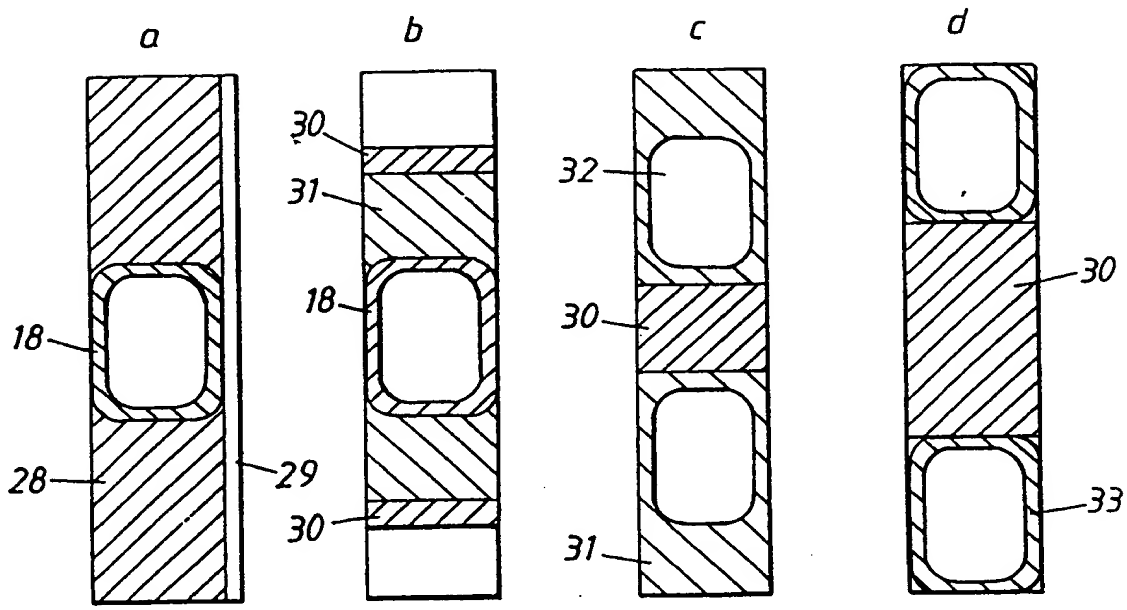
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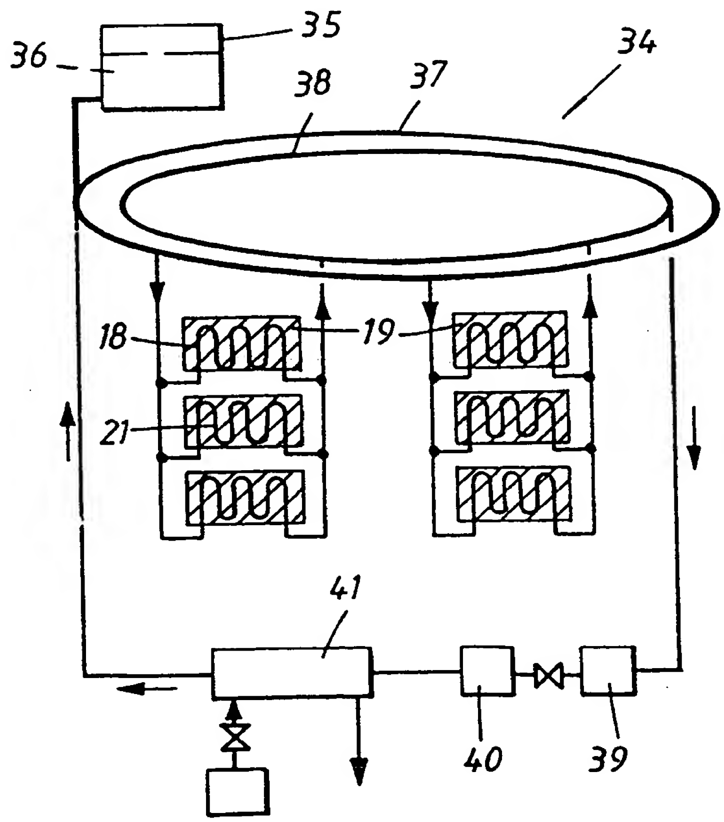
Fig. 7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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00894

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02K 1/20, H02K 3/40, H02K 15/08
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4853565 A (R.K.ELTON ET AL), 1 August 1989 (01.08.89), column 5, line 55 - line 61; column 7, line 12 - line 37, figures 4,7	1-8,11-17
X		18-19
	--	
Y	US 5036165 A (R.K. ELTON ET AL), 30 July 1991 (30.07.91), see the whole document	1-8,11-17
X		18-19
	--	
Y	US 3447002 A (C.RÖNNEVIG), 27 May 1969 (27.05.69), see the whole document	1-8,11-17
X		9-10
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 Sept 1997	09-10- 1997
Name and mailing address of the ISA/ Swedish Pat nt Offic Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00894

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 2917717 C2 (KRAFTWERK UNION AG), 20 August 1987 (20.08.87), see the whole document	1-8,11-17
X		9-10
	--	
Y	US 2217430 A (R.A.BAUDRY), 8 October 1940 (08.10.40), see the whole document	1-8,11-17
X		9-10
	--	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/00894

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1-8,11-17: Relates to a rotating electric machine comprising a winding with semeconducting layers and an embodiment for cooling.
Claims 9-10: Relates to a method of cooling a rotating electric machine
Claims 18-19: Relates to a machine having a magnetic circuit comprising a winding with semiconducting layers.
Claims 9-10 and 18-19 have no special technical features in common.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/09/97

International application No.
PCT/SE 97/00894

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4853565 A	01/08/89	CA 1245270 A	22/11/88
		US 5036165 A	30/07/91
		US 5066881 A	19/11/91
		US 5067046 A	19/11/91
US 5036165 A	30/07/91	US 5066881 A	19/11/91
		US 5067046 A	19/11/91
		CA 1245270 A	22/11/88
		US 4853565 A	01/08/89
US 3447002 A	27/05/69	CH 450535 A	30/04/68
		DE 1513734 A	18/06/70
		FR 1471083 A	22/05/67
		GB 1132997 A	06/11/68
		SE 318939 B	22/12/69
DE 2917717 C2	20/08/87	JP 55147931 A	18/11/80
US 2217430 A	08/10/40	NONE	